Phenotyping rice response to heat: Methodology to discriminate spikelet sterility and grain quality

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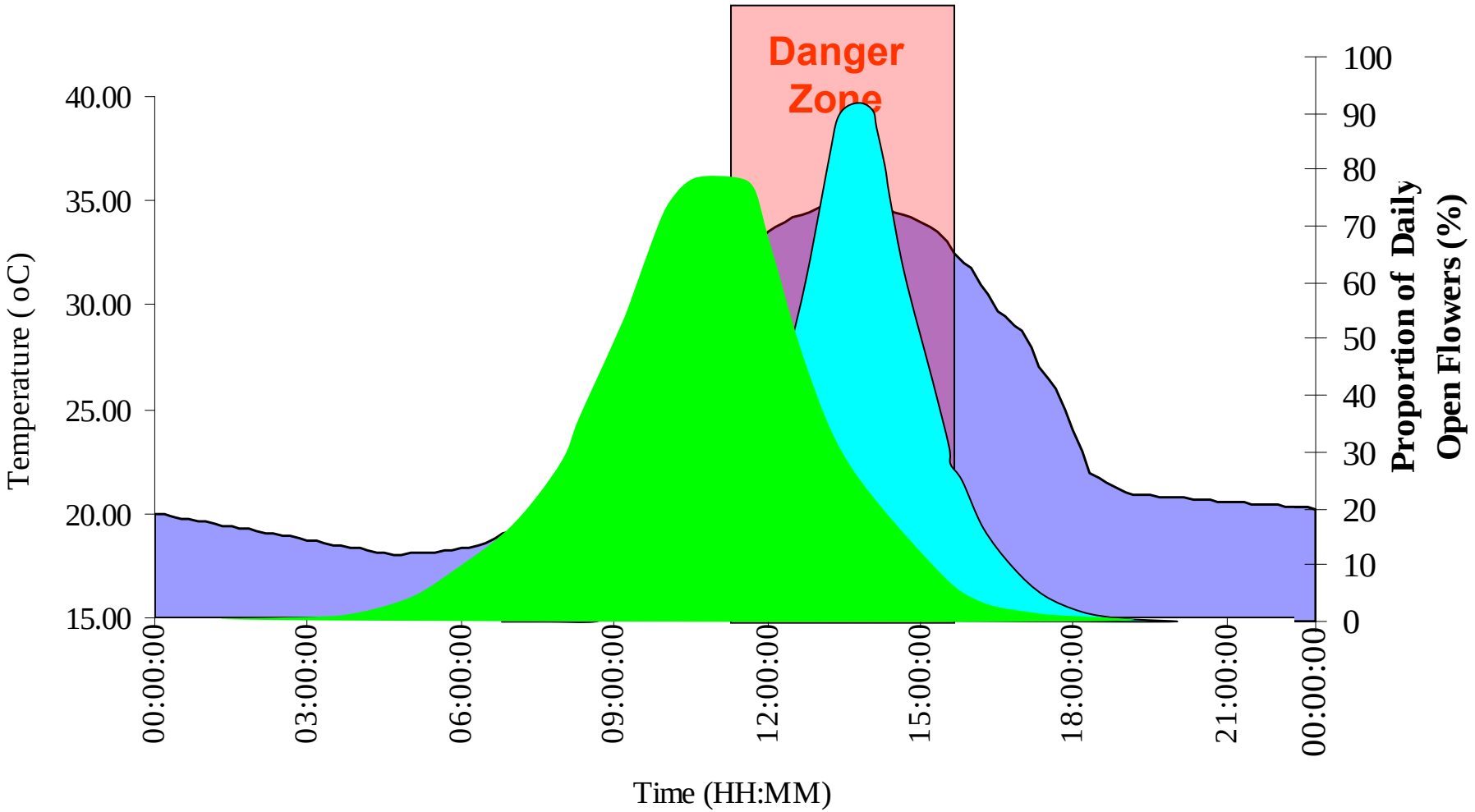
Orytage, 11 December 2009, Cirad

High day temperature effect on spikelet fertility:
Options for canopy adaptation for heat tolerance and avoidance

- Avoidance (*adapted physiology or phenology which allows sensitive stages to occur when temperature is below critical or which maintains temperature below critical*):
  - early Time of the Day of Flowering (TDF)
  - favorable canopy architecture
  - high rate of transpirational cooling (panicle and leaf transpiration)
  - anthesis disynchrony among panicles of the same plant

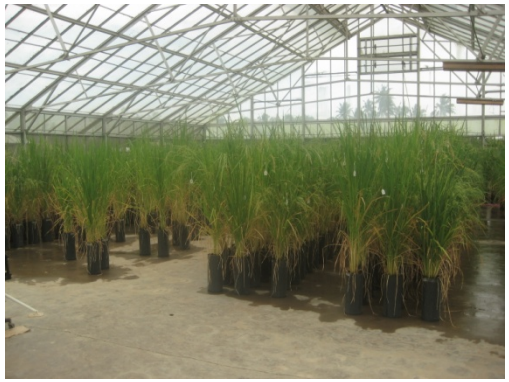
- Tolerance (*adapted physiological and biochemical systems able to withstand at temperature above critical*):
  - high rate of anther dehisence and anthesis: high fertility rate
  - high grain filling rate including high remobilization: good grain quality

High day temperature effect on spikelet fertility:
Principles for avoidance with time of the day of flowering



High day temperature effect on spikelet fertility:
Avoidance: method to account for time of the day of flowering

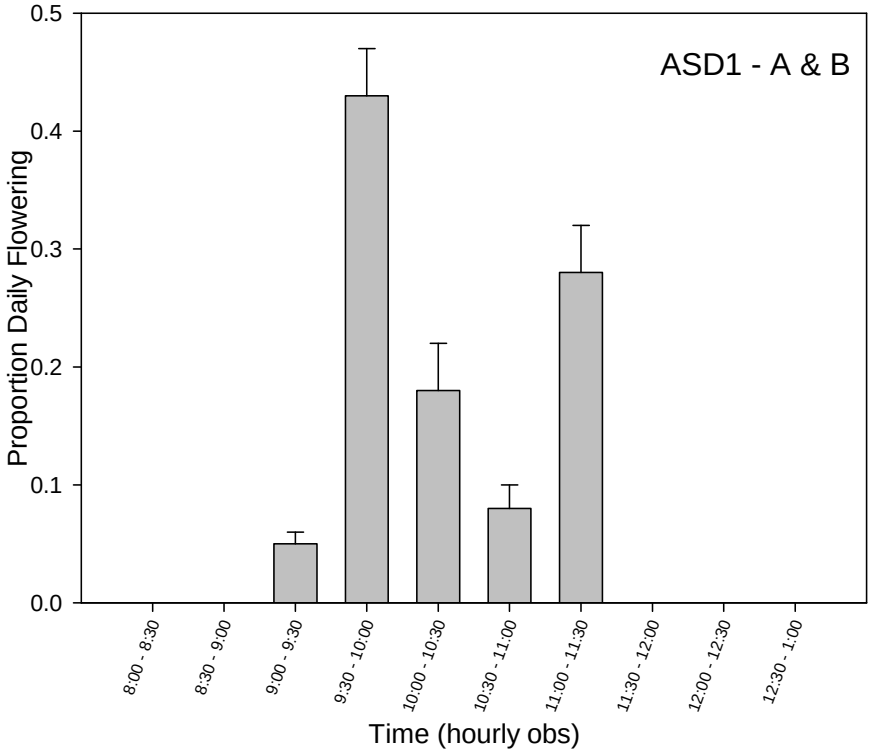
Phenotyping for heat avoidance

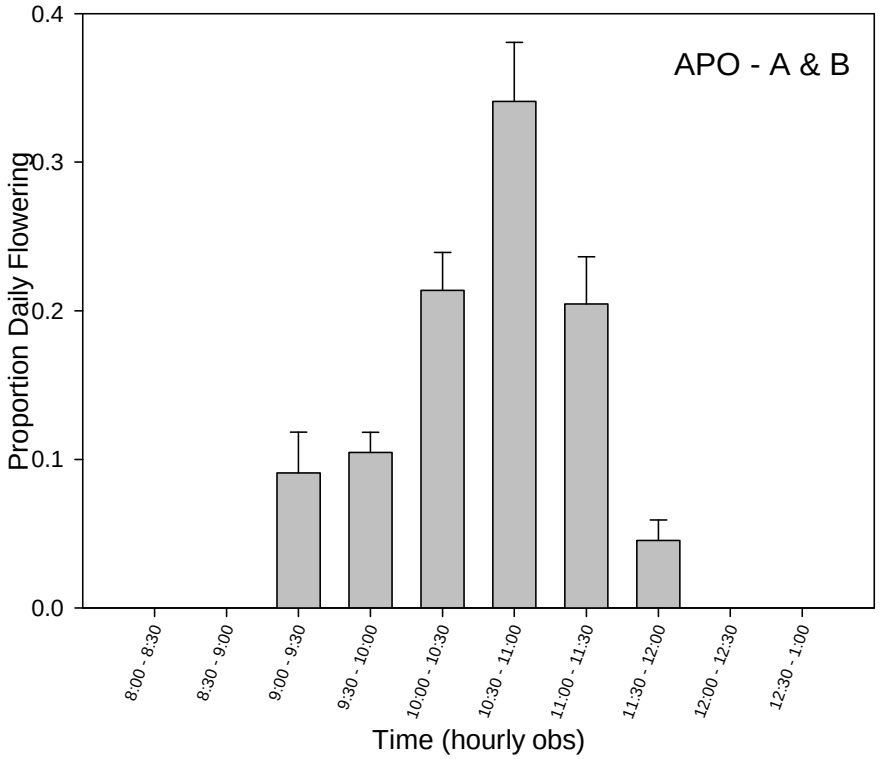


Observing the process of anthesis along the panicle every 30 minutes

High day temperature effect on spikelet fertility:
Avoidance: some results of the time of the day of flowering

What was observed here was the time of the day of flowering
of the first 10 spikelets of the day, not of the peak of the day





High day temperature effect on spikelet fertility:
Principles for avoidance with favorable plant architecture

- The tissue temperature is different from the ambient temperature with respect to the local environment (radiation, temperature and relative humidity inside the canopy, soil and water temperature), to the spatial position and orientation of the organ and to the physiological processes (transpiration)
- There is a genotypic variability for the plant architecture and for the response of the physiological processes to the environment: in the same environment, the tissue (panicle) temperature will vary between genotypes
- The characterization of plant architecture provides some information on the ability of the plant to reduce the panicle temperature: size of the plant leaf area, position and shape of the panicle, distance between the flag leaf and the panicle

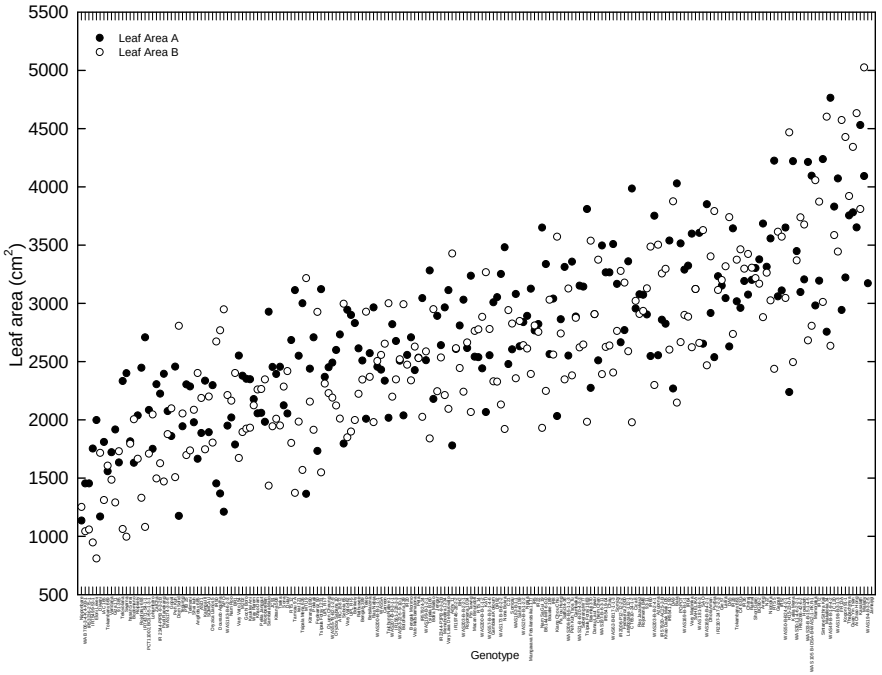
High day temperature effect on spikelet fertility:
Avoidance: methodology to characterize plant architecture

Characterizing the plant (architecture and biomass) at flowering

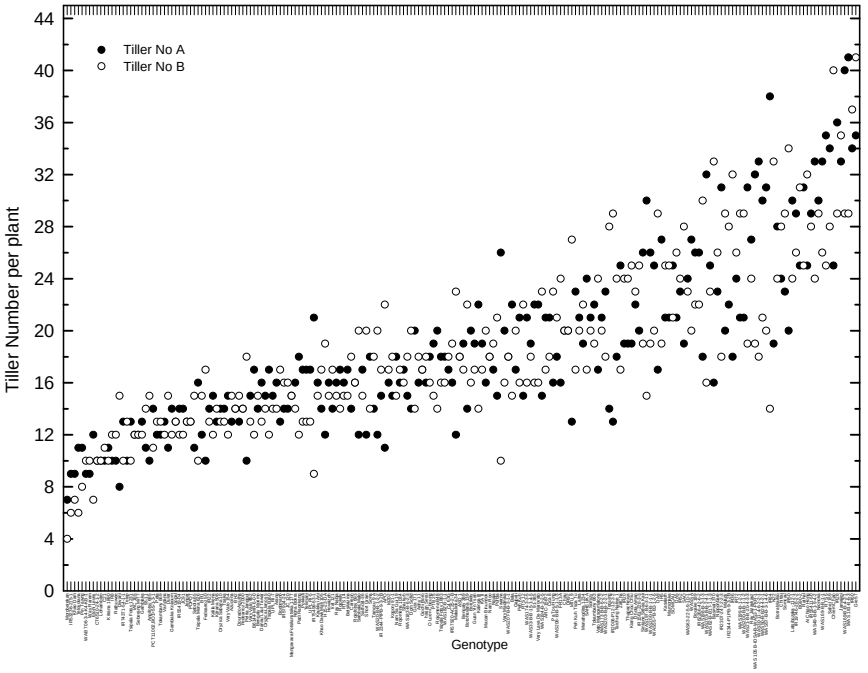
Characterizing the plant architecture (panicle width, leaf angle, plant height) and collecting plant leaf area and plant biomass

High day temperature effect on spikelet fertility:
Avoidance: variability of tiller and leaf area at flowering

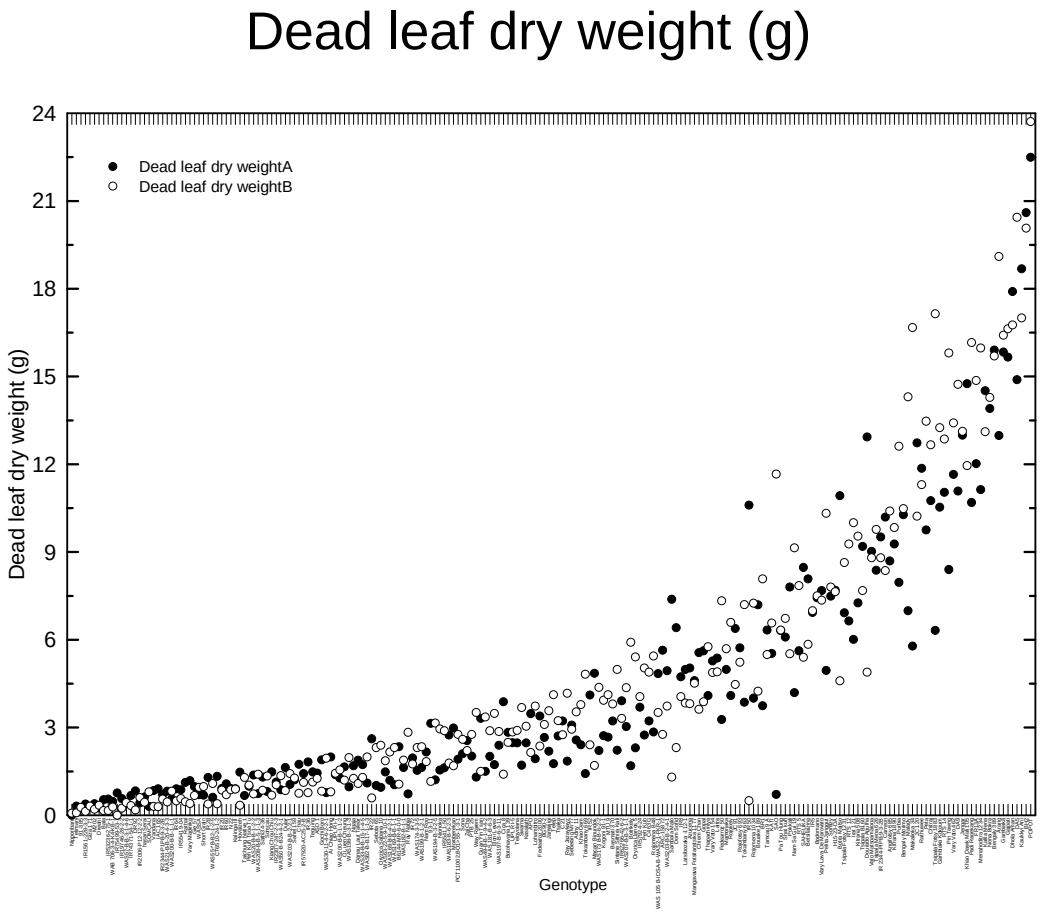
Leaf area per plant (cm^2)



Tiller number per plant

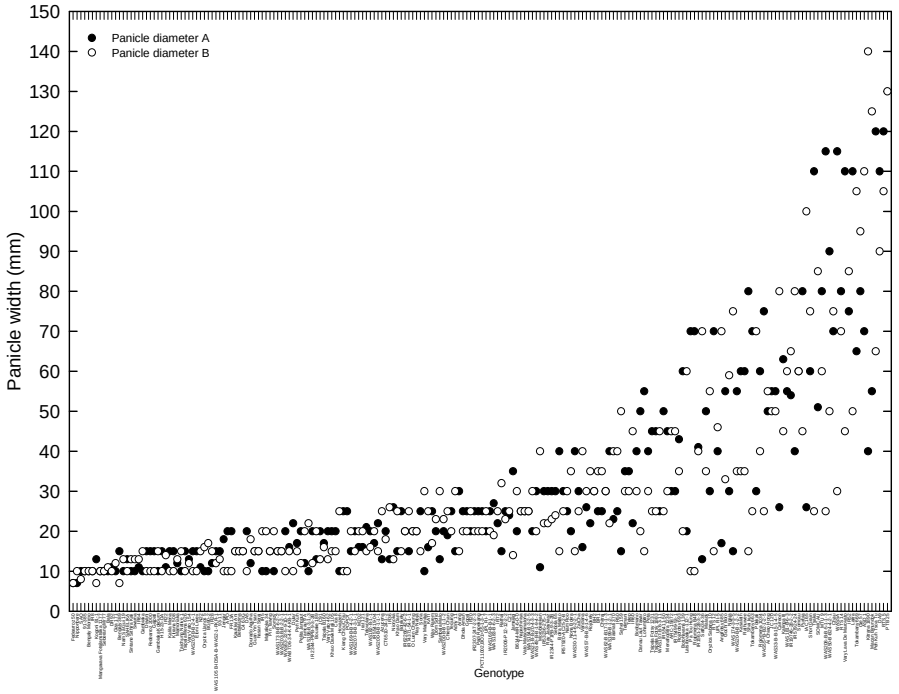


High day temperature effect on spikelet fertility:
Avoidance: variability of plant dead leaf dry weight at flowering

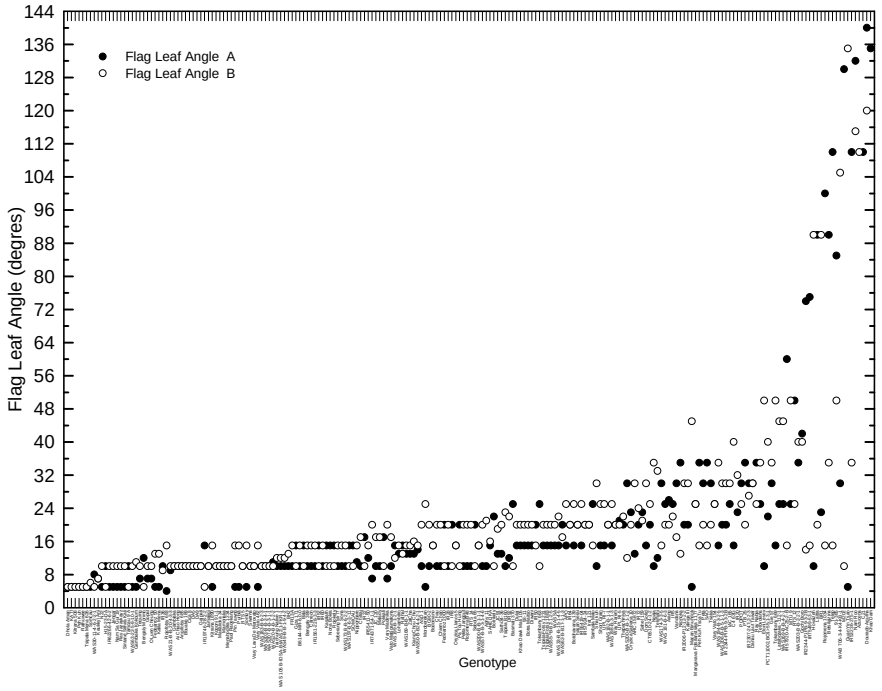


High day temperature effect on spikelet fertility:
Avoidance: variability of the panicle shape and flag leaf angle

Panicle width (mm)

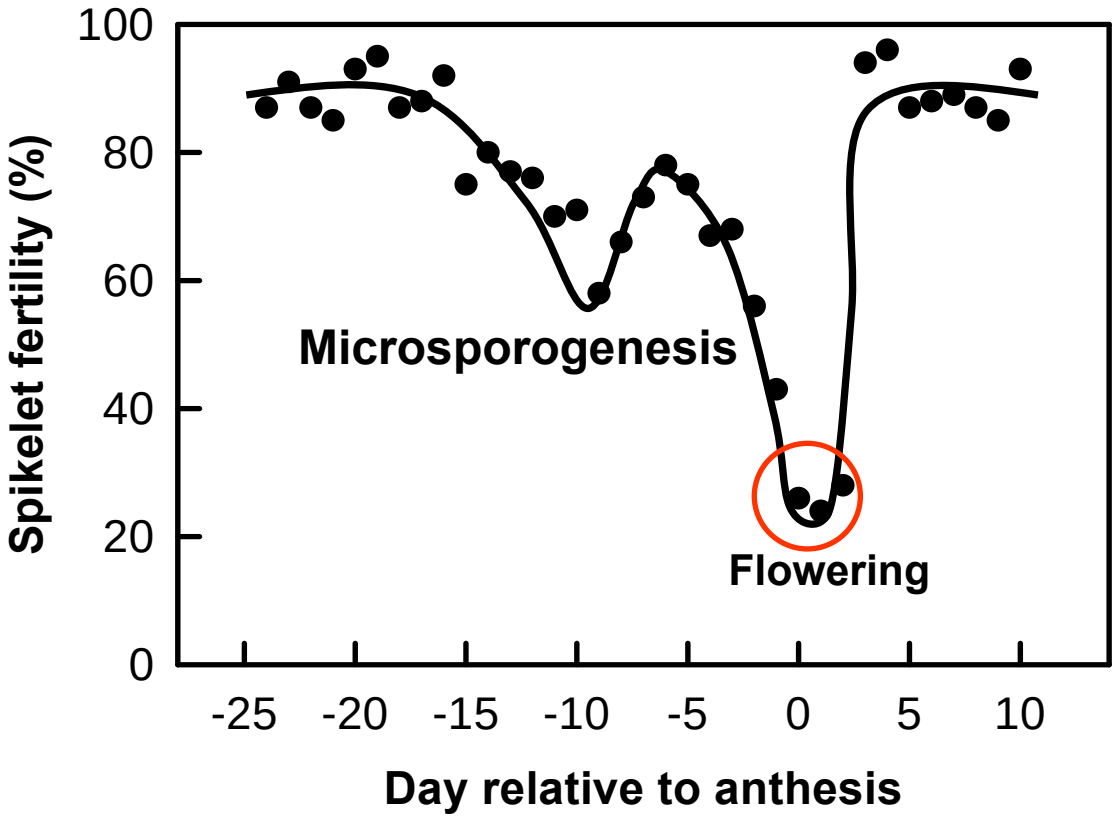


Flag leaf angle (degres)



High day temperature effect on spikelet fertility:
Principles for tolerance with the sensitivity to temperature

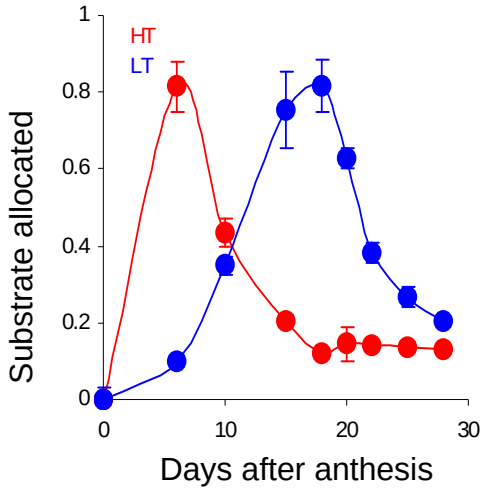
Effect on spikelet sterility of 38°C ambient temperature



Redrawn from Satake & Yoshida, 1978

How does the fertility ratio vary with genotype?

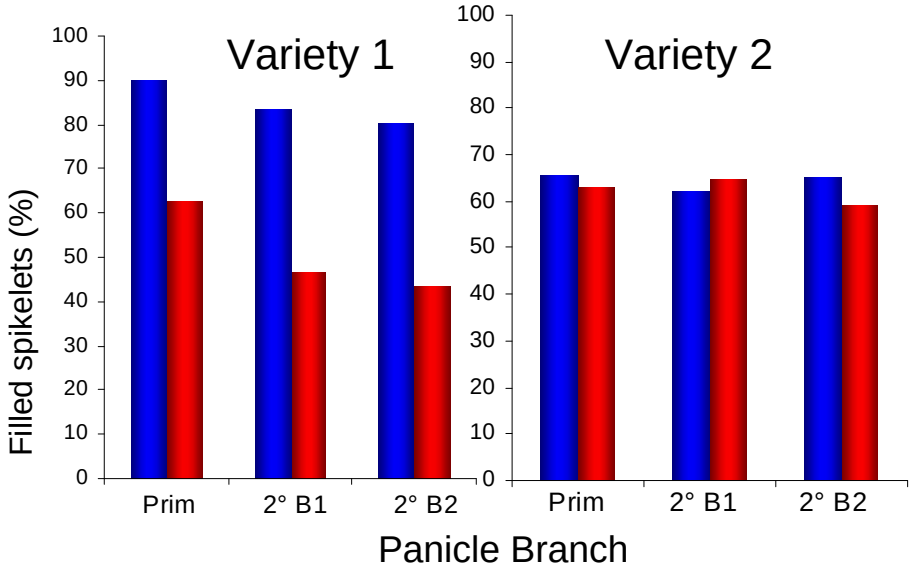
High day temperature effect on grain quality:
Principles for tolerance with respect to panicle structure



Data from Melissa Fitzgerald

- Substrates only allocated to the panicle for half of the time at high temperature
- Grains in secondary positions of a panicle get a lesser chance to fill, so are subjected to chalkiness and immaturity

The morphology of the panicle, as the ratio of secondary spikelets, could be used as a trait for screening



- When spikelets are maintained, each grain is 25% lighter, with fewer starch granules, and all grains are chalky
- When spikelets are sacrificed, more grains are unfilled, but quality is good

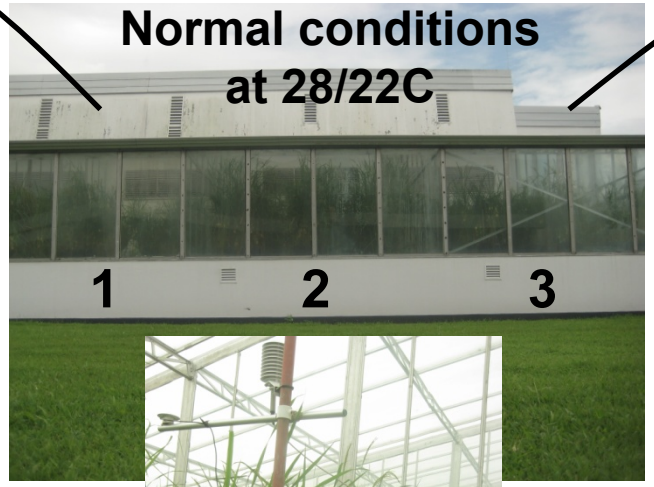
In high temperature, some varieties sacrifice spikelets, and some do not. Yield decreases for both, but quality is better for V1 than for V2

High day temperature effect on spikelet fertility and grain quality:
Tolerance: methodology to quantify plant sensitivity

IRRI: phenotyping for heat tolerance and avoidance on grain yield and quality

10 days at 32/22C after flowering

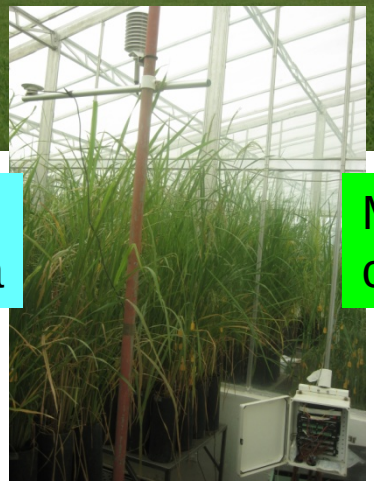
Normal conditions at 28/22C



5 days at 38/22C at anthesis

Tagging flowering date of each panicle

Measuring weather data



Measuring canopy data

Collecting spikelet sterility and grain starch content

Separating filled and unfilled spikelet

High day temperature effect on spikelet fertility and grain quality:
Tolerance: precautions taken in the experimental setup

- To tag each single panicle of the stressed plants with respect to the day of flowering in order to characterize what the environment was on the day of flowering
- To tag each single panicle of the control plants with respect to the day of flowering in order to compare similar panicles between stressed and control plants
- To cut the panicle into 2 pieces (top and bottom) and to compare the top parts of the panicle to assess for spikelet fertility and grain quality: the point is to avoid to account for unfilled grain due to lack of supply
- Was the 38C treatment too strong for discrimination?
- Bad control of the 34C treatment to assess tolerance to grain quality because of dependance of the external conditions

High day temperature effect on spikelet fertility:
New avoidance: emergence of extra tillers after flowering

Initial panicle totally sterile at maturity because of heat

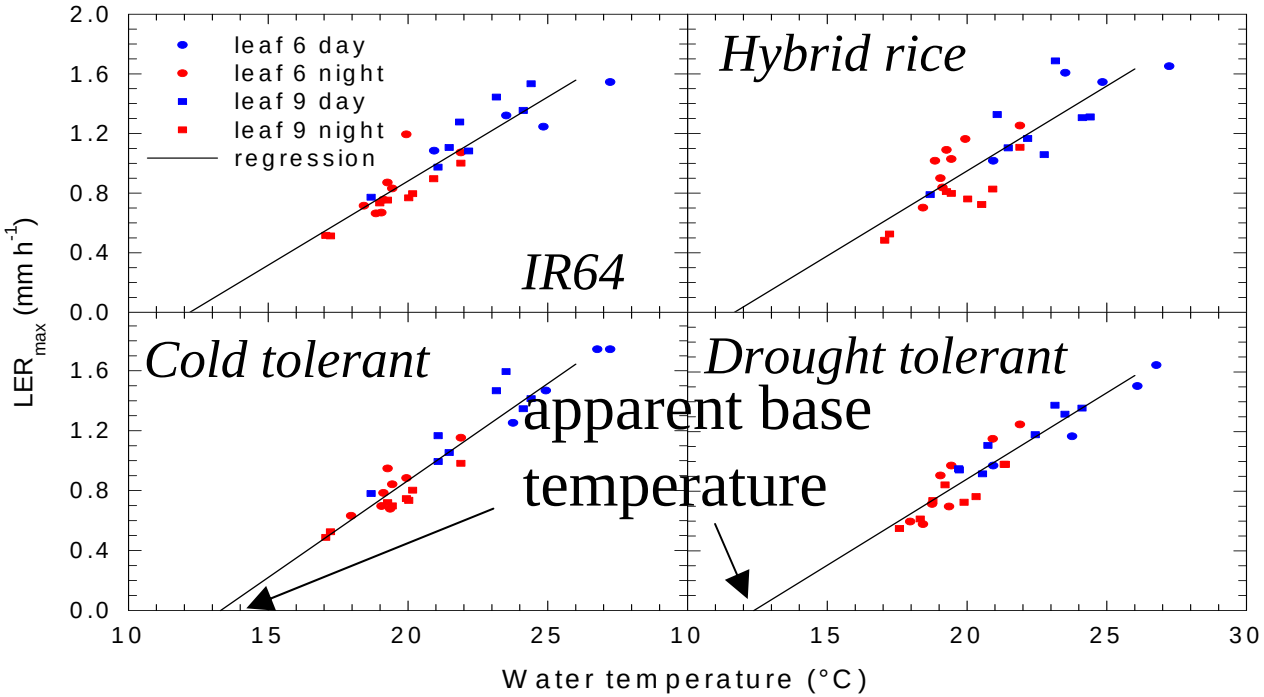
Panicles newly formed after flowering

Newly formed tillers attached to upper nodes of the mother tiller

Tillering plasticity as an avoidance mechanism to cope with spikelet sterility under heat

High day temperature effect on biomass accumulation and partitioning: Investigating the day and night temperature effect on LER

Investigating the day and night temperature effect on underlying straight forward processes driving leaf area, like organ elongation, under low VPD



For each variety, normalized slopes and x-intercepts of leaf elongation did not differ for day and night time periods

The threshold temperature (x-intercept) varied from 10.4 to 13.6°C when considering 16 contrasted genotypes

Plant models should account for the genotype variability of the growth response to temperature: development of Oryza2000 for phenology and growth response to high temperature **Work of Pepijin van Oort, Wageningen University**